

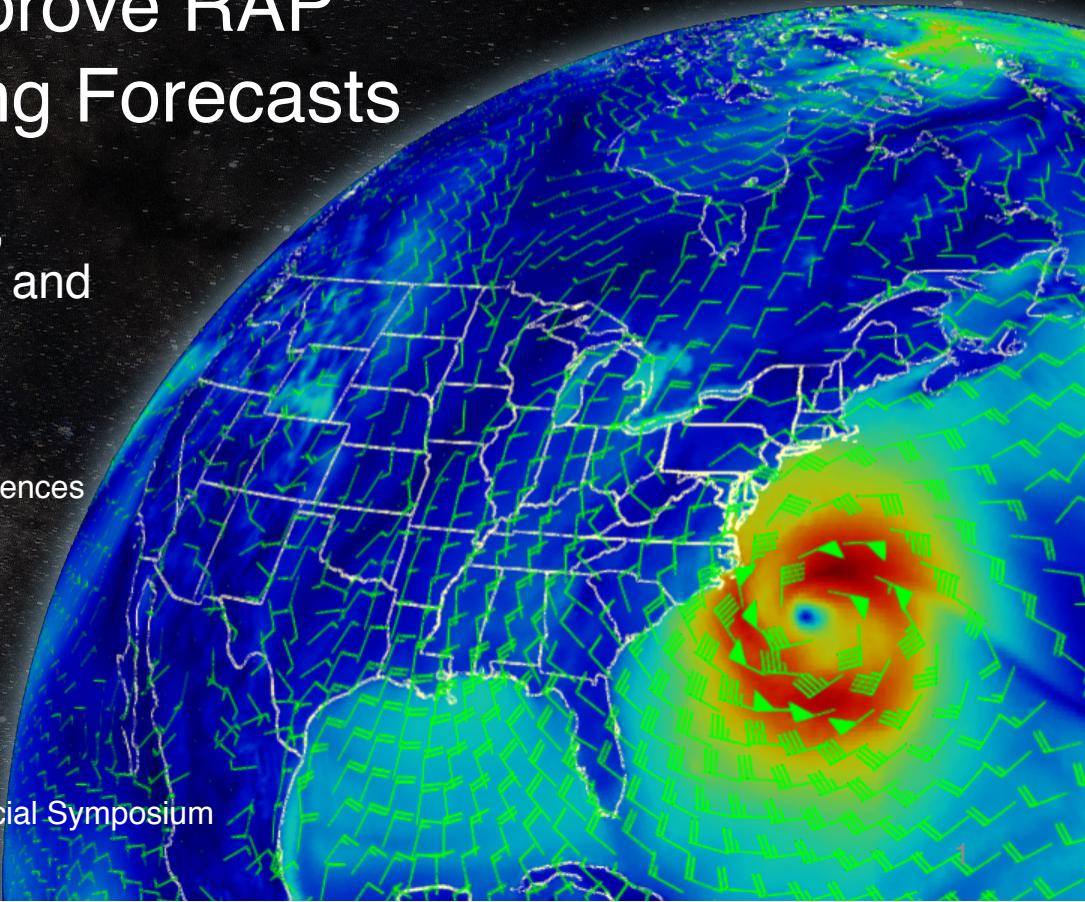
Application of a Subgrid-Scale Cloud Parameterization to Improve RAP and HRRR Cloud-Ceiling Forecasts

Jaymes S. Kenyon, Joseph B. Olson,
John M. Brown, Wayne M. Angevine, and
Greg Thompson

NOAA / Earth System Research Laboratory, and
Cooperative Institute for Research in Environmental Sciences
Boulder, Colorado



Fifth Aviation, Range, and Aerospace Meteorology Special Symposium
13 January 2016 | New Orleans, Louisiana





RAP and HRRR: Hourly-Updated Forecast Models

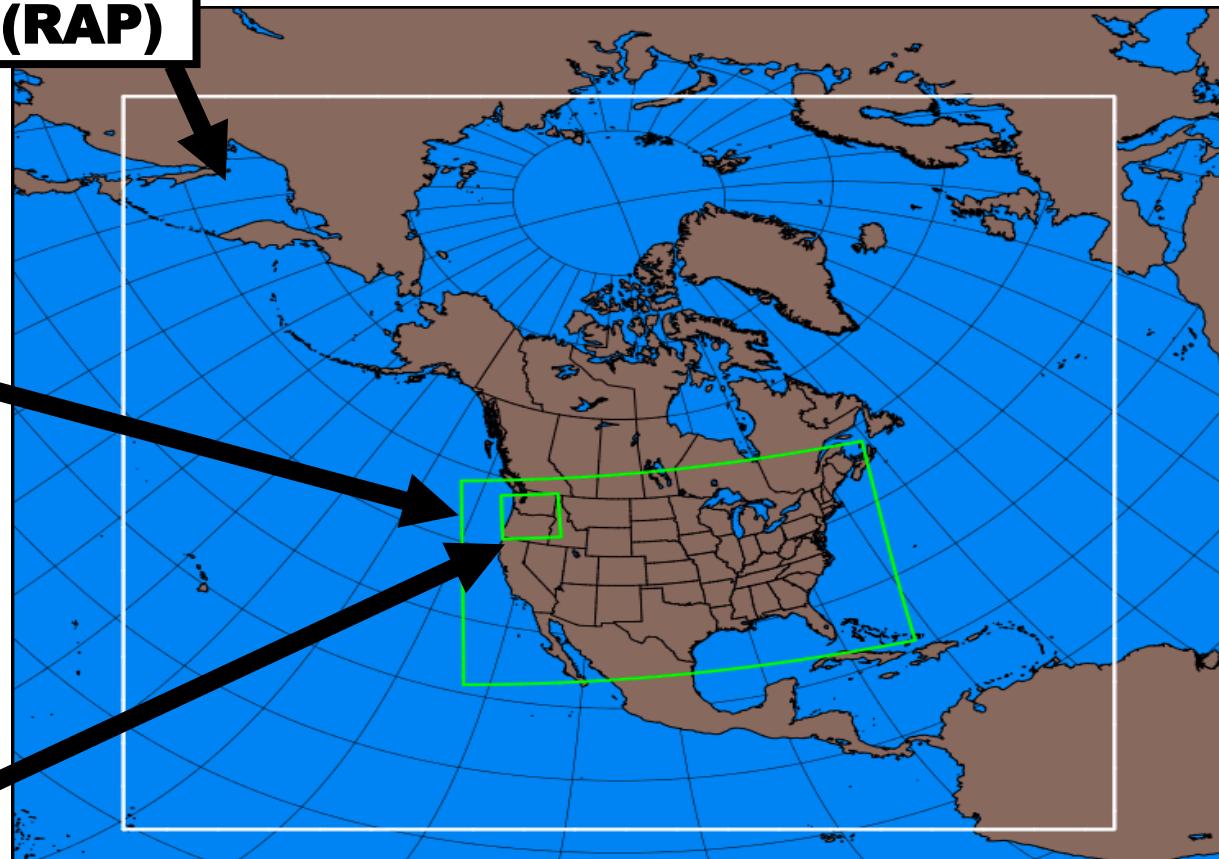
13-km Rapid Refresh (RAP)

Initial & Lateral Boundary
Conditions

3-km High- Resolution Rapid Refresh (HRRR)

Initial & Lateral Boundary
Conditions

750-m HRRR-WFIP2 nest

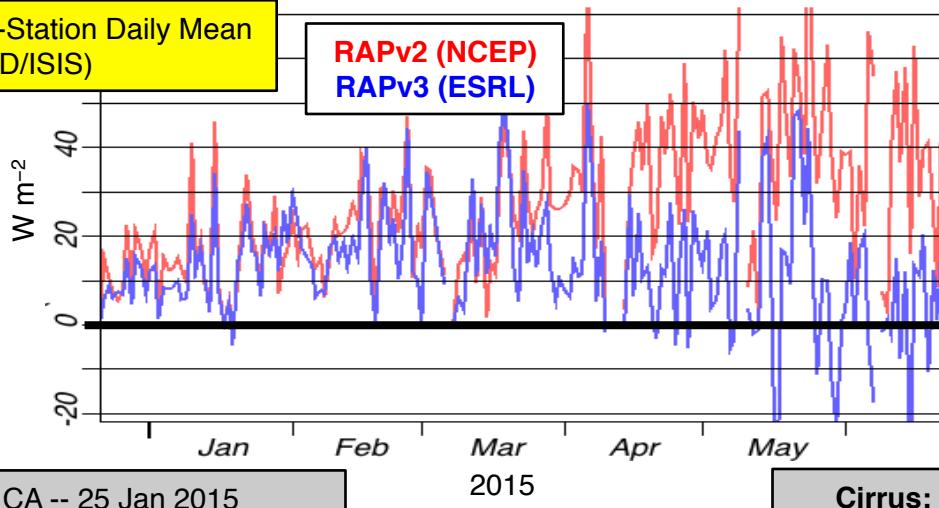




RAP Solar Irradiance (GHI) Biases

6-h Forecast Bias: 14-Station Daily Mean
(SURFRAD/ISIS)

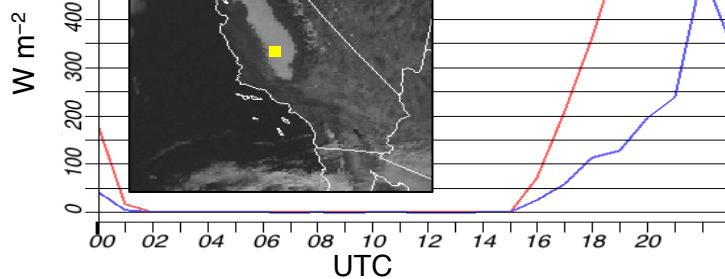
RAPv2 (NCEP)
RAPv3 (ESRL)



Shallow Cumulus

Stratus: Hanford, CA -- 25 Jan 2015

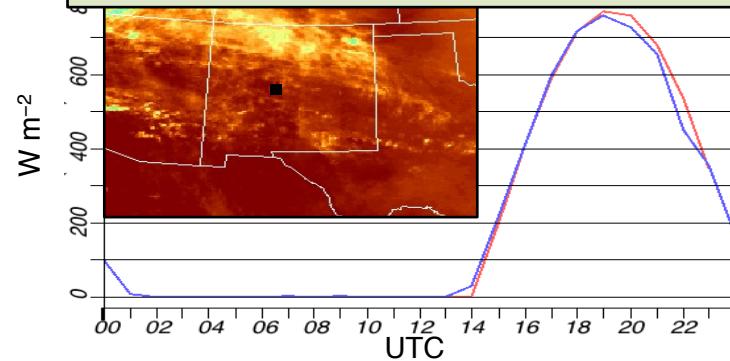
KVIS 251835Z AUTO 00000KT 1/4SM OVC002



6-h Forecast: RAPv3
Measured: ISIS

Cirrus: Albuquerque, NM -- 19 Feb 2015

KABQ 192052Z 21005KT 10SM SCT250



0	0	0	0
0	1	1	0
0	0	0	0

Cloud Fraction

0	0	0	0.3
0.5	1	1	0
0.25	0.5	0.5	0

Cloud Fraction

**Grid-Scale Clouds
Represented Within:**

**Subgrid-Scale Clouds
Represented Within:**

**Microphysics
(Thompson–Eidhammer)**

Coupled To...

**Model
Prognostic
Variables**

Radiation (RRTMG)

Tendencies

Tendencies

Deep Convection (GF)

Tendencies

Shallow Convection (GFO)

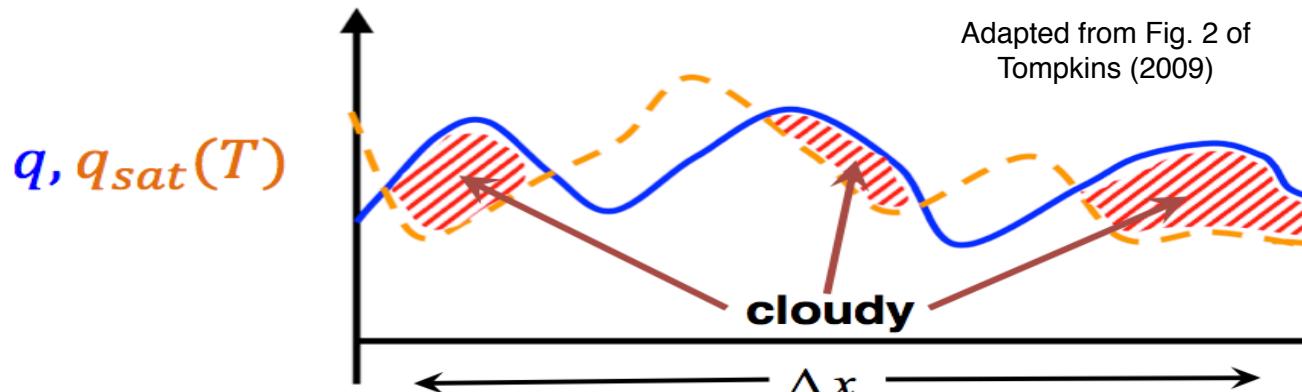
Tendencies

Turbulence (MYNN)

Coupled To...



Overview of Statistical Cloud Parameterizations



$$Var(s) \propto Var(q) + Var(T) - Cov(q, T)$$

Assume a PDF of s

Retrieve Cloud Fraction,
Cloud Condensate

Parameterize:
assume subgrid PDFs for thermodynamic variables

Sommeria and Deardorff (1977) and Mellor (1977)

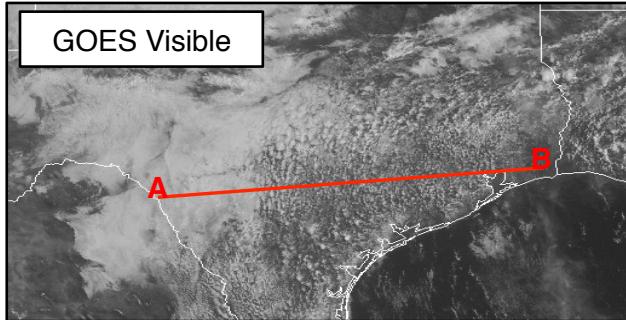
- Gaussian joint distributions

Chaboureau and Bechtold (2002)

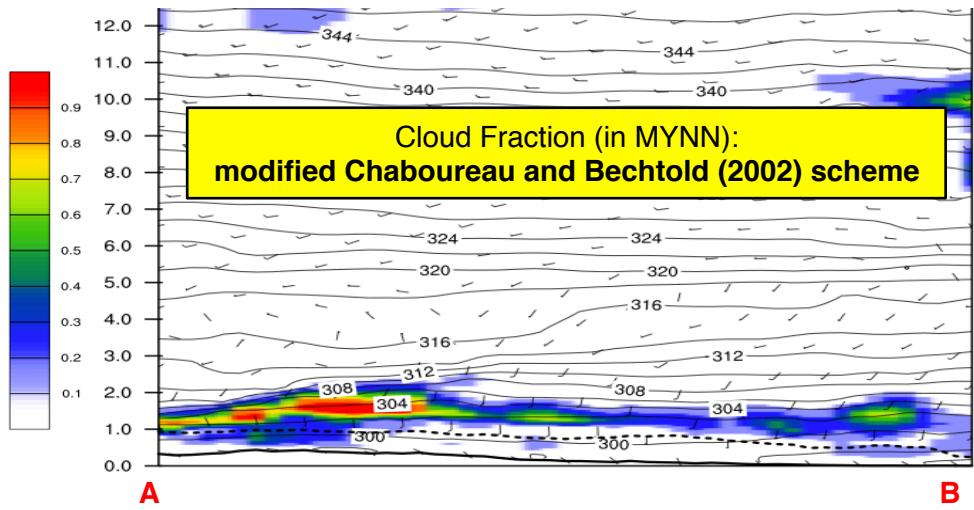
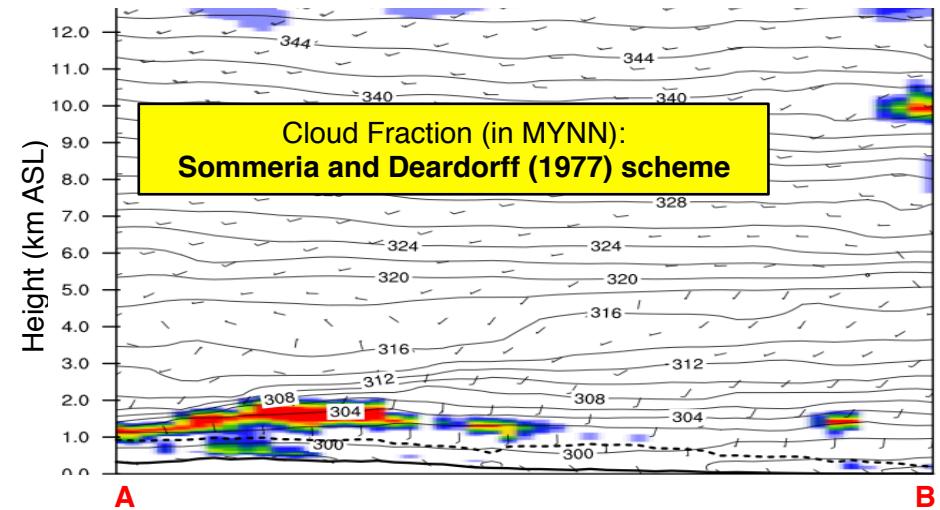
- Allows for skewed distributions
- May be implemented diagnostically or prognostically



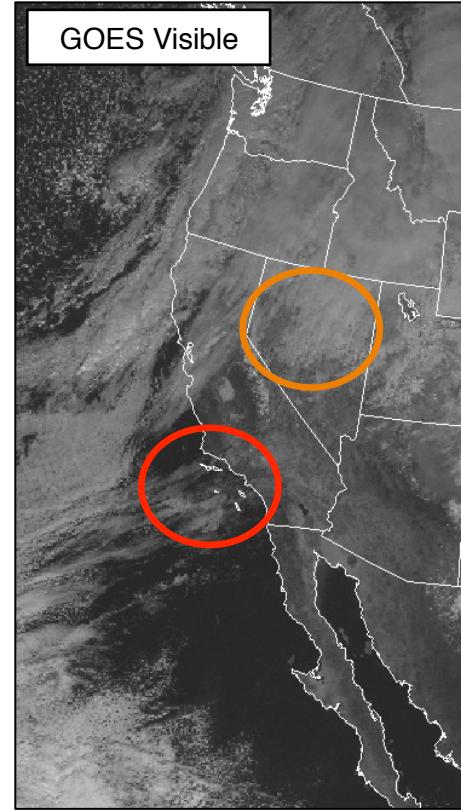
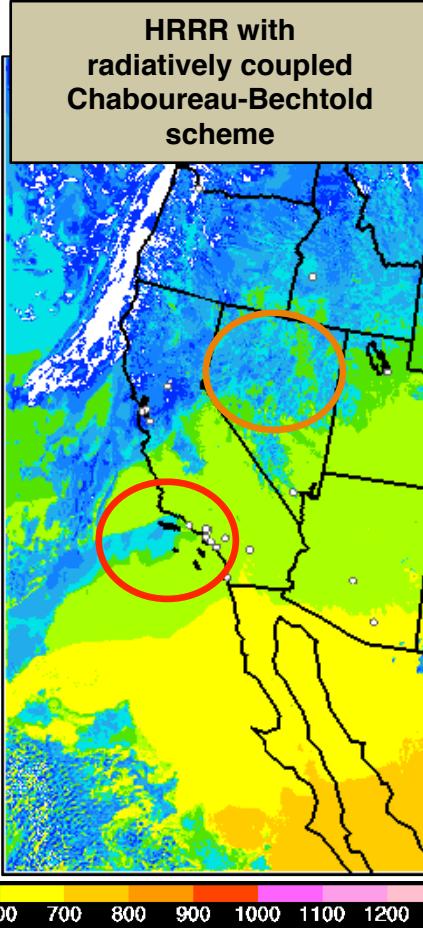
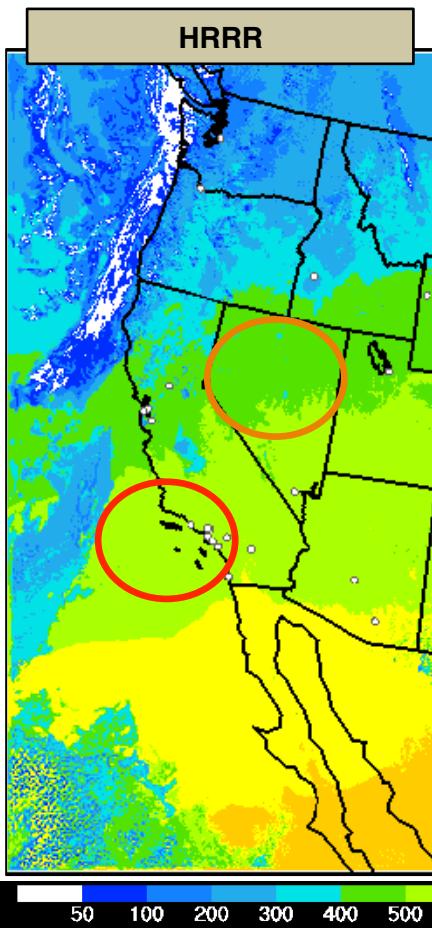
Example: RAP 3-h Forecasts Valid 1500 UTC 20 May 2015



- Chaboureau and Bechtold (2002) scheme is “active” in stratocumulus, cumulus, and cirrus regions
- Better able to represent low–intermediate cloud fractions



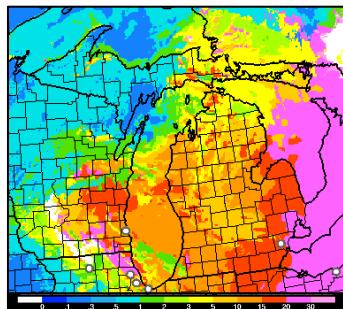
Example: HRRR 1-h GHI Forecasts Valid 1900 UTC 27 Dec 2015



- Chaboureau and Bechtold (2002) scheme provides additional source of subgrid clouds for radiative flux forecasts



Ceiling Diagnostic Algorithm in the RAP and HRRR



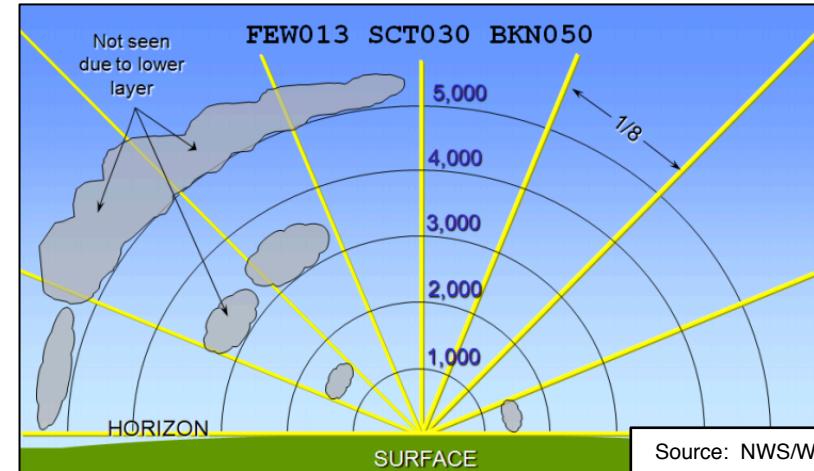
For each grid column, ceiling is diagnosed where:

- grid-scale $q_c + q_i > 10^{-6} \text{ g g}^{-1}$, or
- grid-scale RH at PBL top > 95%
- Thin, surface-based cloud layers (< ~80 m deep) are disregarded
- If grid-scale snow is present, the diagnosed ceiling is lowered

From FAA 7900.5B:

Ceiling: the height above the earth's surface (field elevation or ground elevation) ascribed to the lowest non-surface-based layer that is reported broken or overcast, or the vertical visibility into a surface-based obscuration that totally hides the sky.

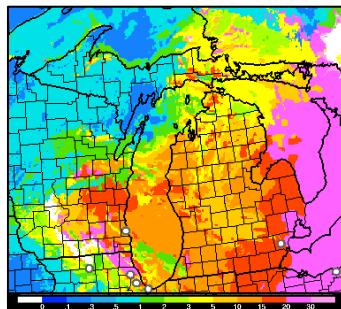
Broken: represents sky cover of 5/8ths up to, but not including, 8/8 at and below the level of a layer aloft.



Source: NWS/WDTB



Ceiling Diagnostic Algorithm in the RAP and HRRR



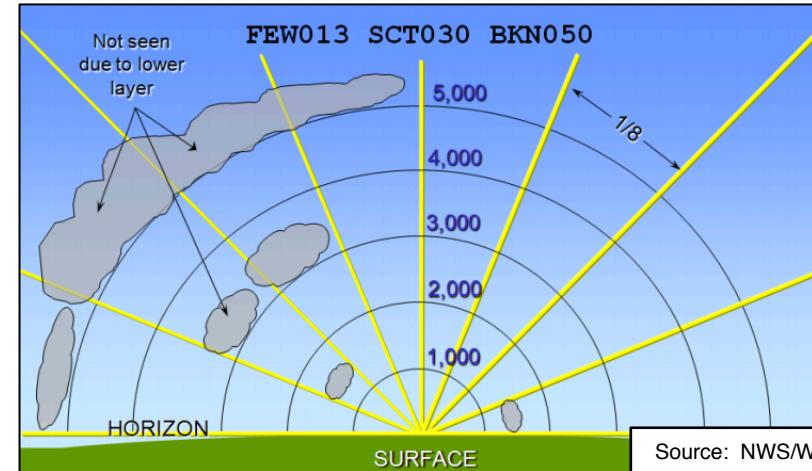
For each grid column, ceiling is diagnosed where:

- ~~grid-scale $q_c + q_i > 10^{-6} \text{ g g}^{-1}$, or~~
 - ~~grid-scale RH at PBL top > 95%~~
 - Thin, surface-based cloud layers (< ~80 m deep) are disregarded
 - If grid-scale snow is present, the diagnosed ceiling is lowered
- Experimental New Algorithm →
- master cloud fraction > 0.5

From FAA 7900.5B:

Ceiling: the height above the earth's surface (field elevation or ground elevation) ascribed to the lowest non-surface-based layer that is reported broken or overcast, or the vertical visibility into a surface-based obscuration that totally hides the sky.

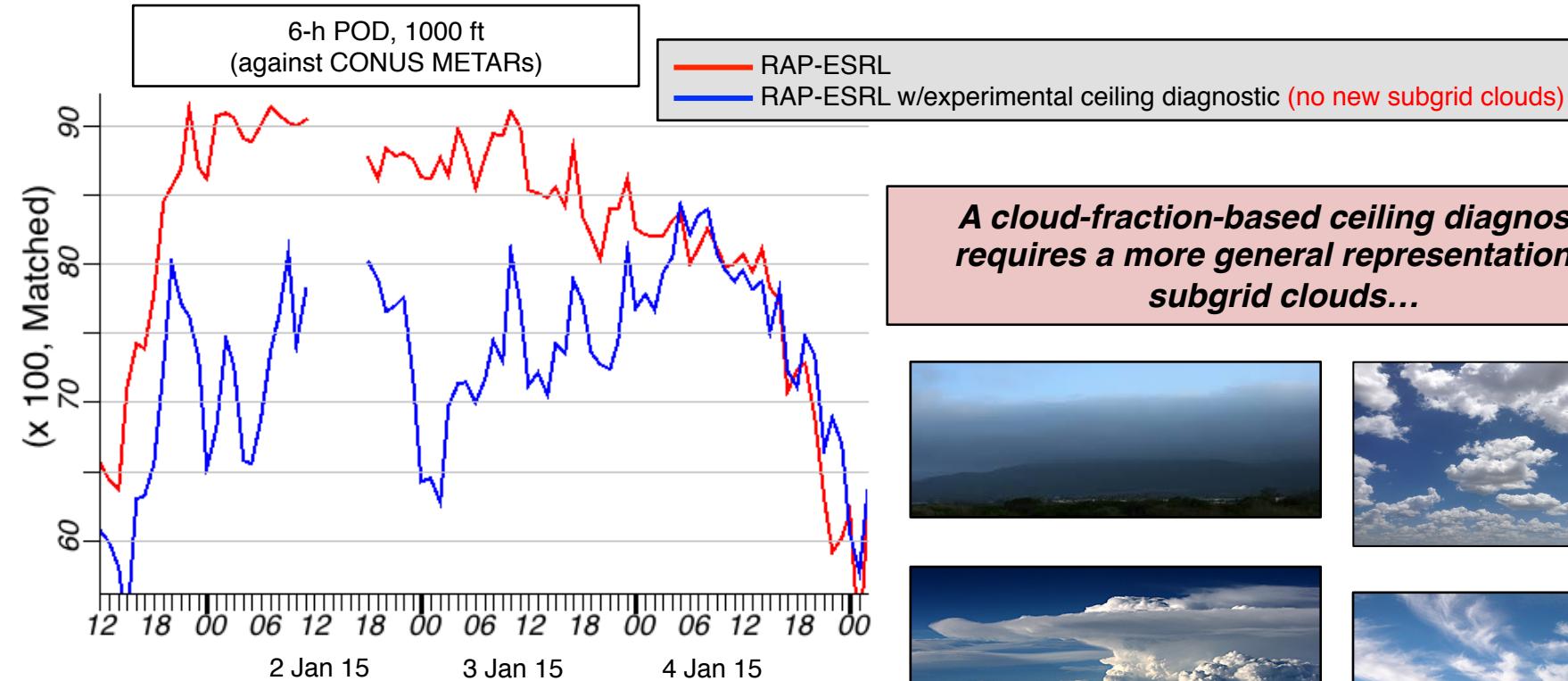
Broken: represents sky cover of 5/8ths up to, but not including, 8/8 at and below the level of a layer aloft.



Source: NWS/WDTB



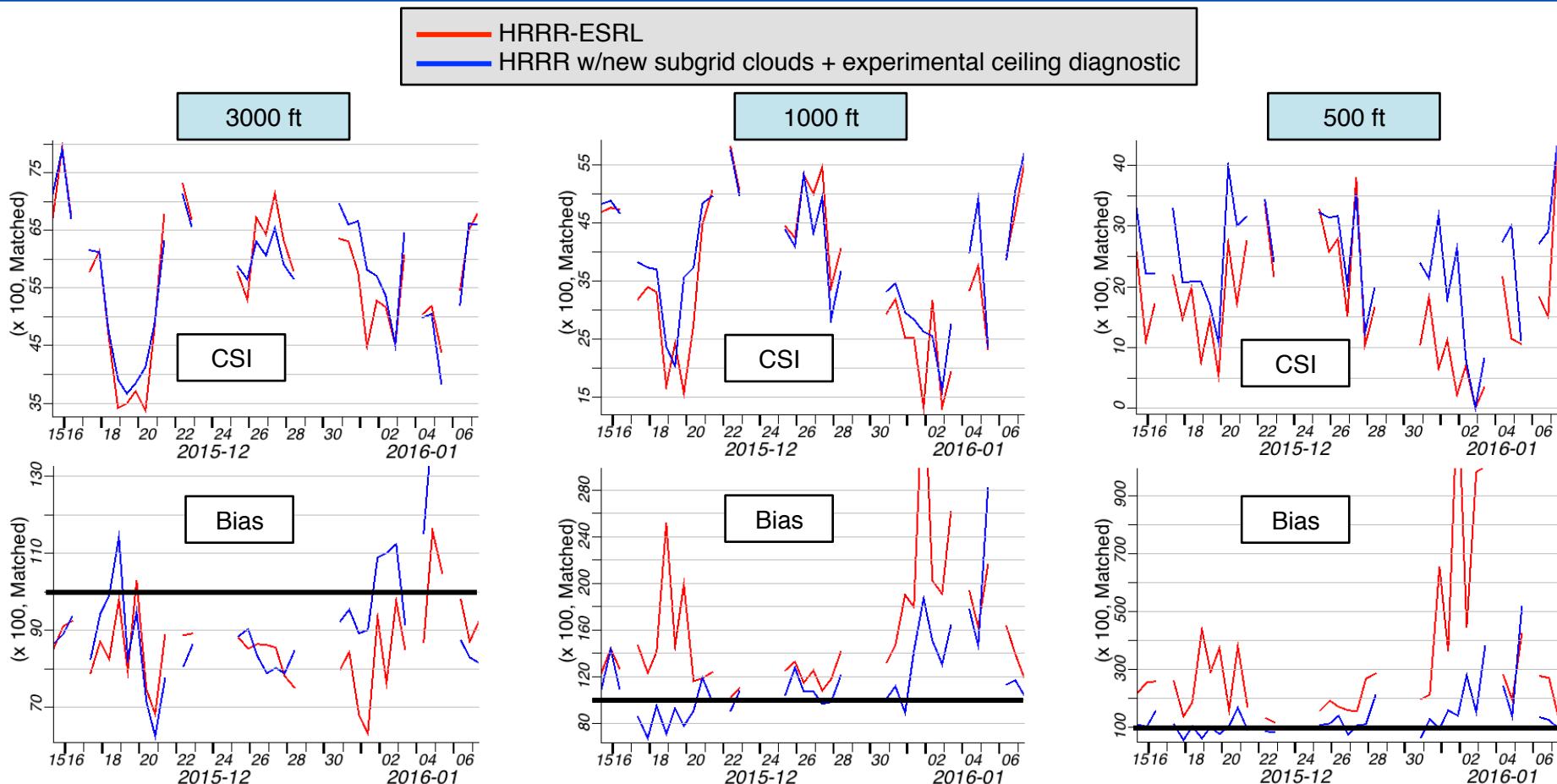
Towards a Cloud-Fraction-Based Ceiling Diagnostic



A cloud-fraction-based ceiling diagnostic requires a more general representation of subgrid clouds...



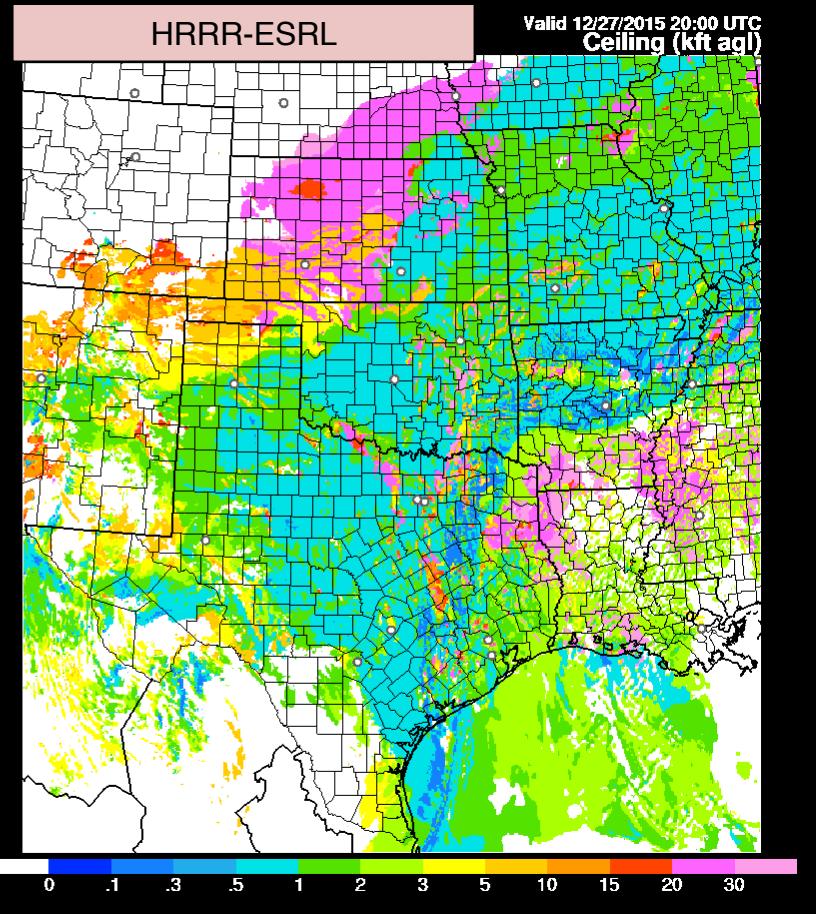
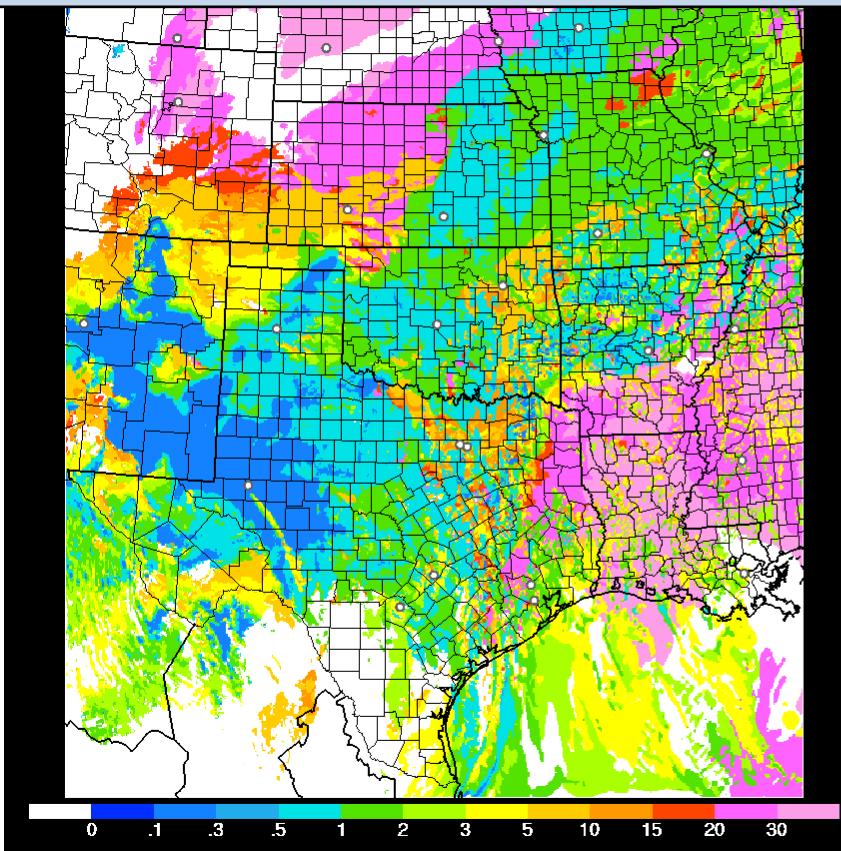
Ceiling Verification: 3-h forecasts against CONUS METARS





Example: 27–28 December 2015

HRRR w/new subgrid clouds + experimental ceiling diagnostic



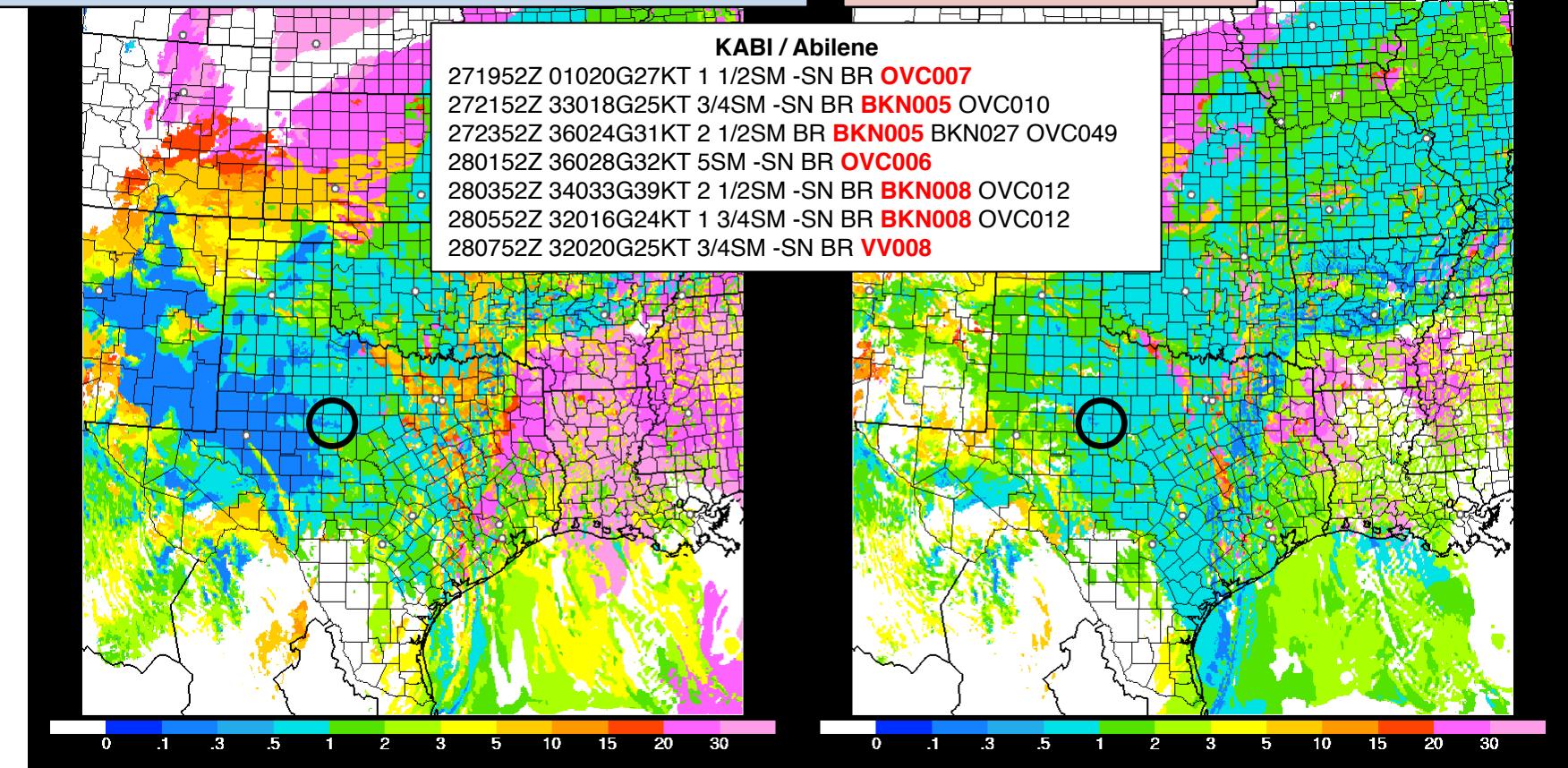


Example: 27–28 December 2015

HRRR w/new subgrid clouds + experimental ceiling diagnostic

HRRR-ESRL

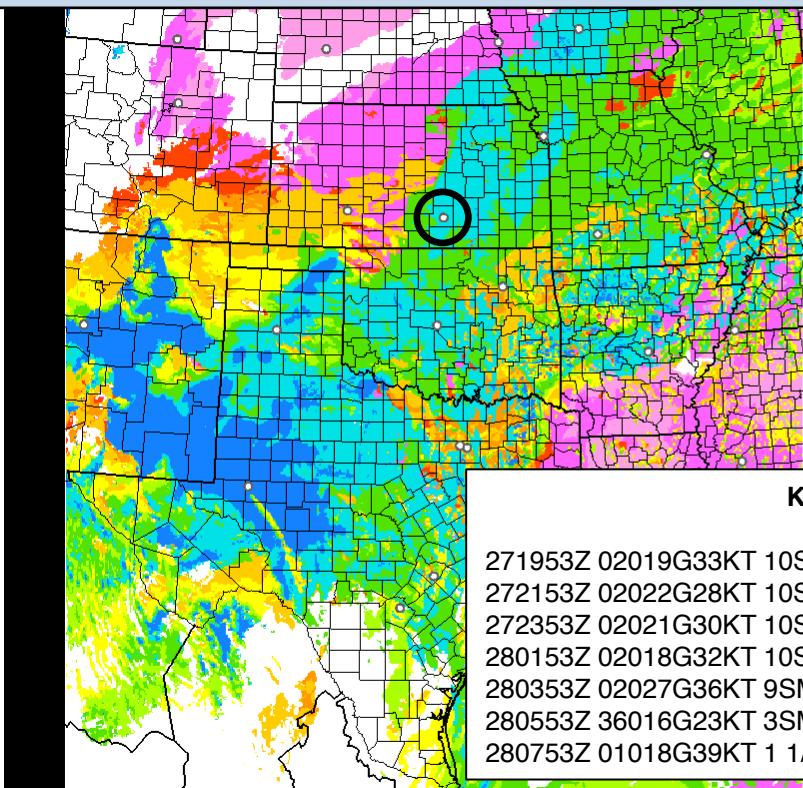
Valid 12/27/2015 20:00 UTC
Ceiling (kft agl)





Example: 27–28 December 2015

HRRR w/new subgrid clouds + experimental ceiling diagnostic



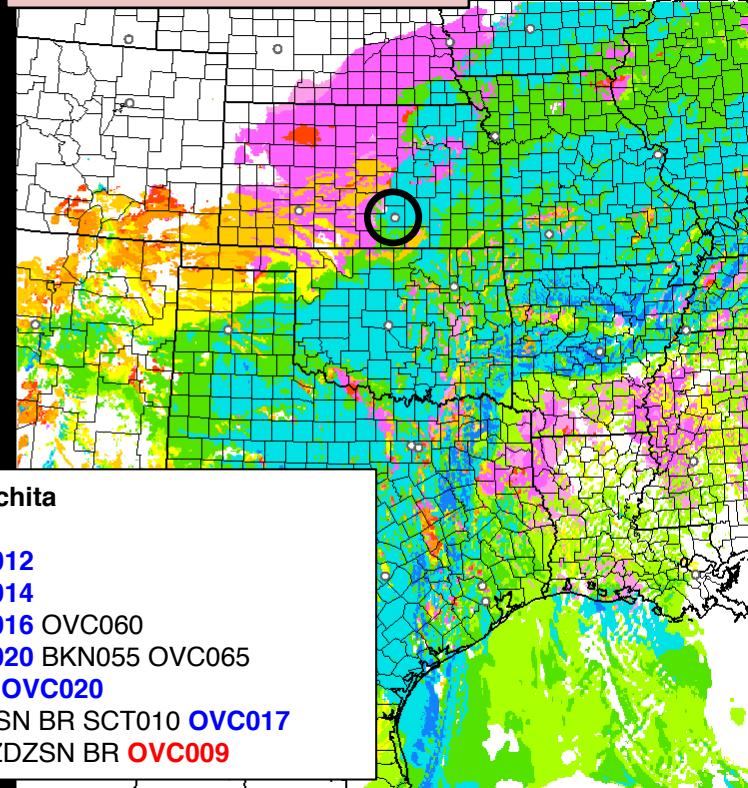
KICT / Wichita

271953Z 02019G33KT 10SM **OVC012**
272153Z 02022G28KT 10SM **OVC014**
272353Z 02021G30KT 10SM **BKN016** OVC060
280153Z 02018G32KT 10SM **BKN020** BKN055 OVC065
280353Z 02027G36KT 9SM -FZDZ **OVC020**
280553Z 36016G23KT 3SM -FZDZSN BR SCT010 **OVC017**
280753Z 01018G39KT 1 1/2SM -FZDZSN BR **OVC009**



HRRR-ESRL

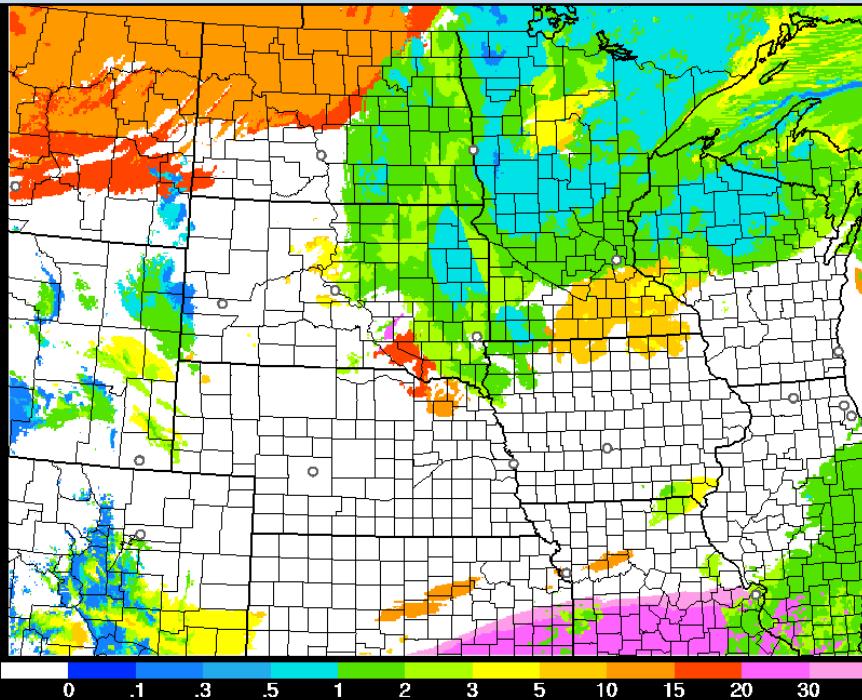
Valid 12/27/2015 20:00 UTC
Ceiling (kft agl)



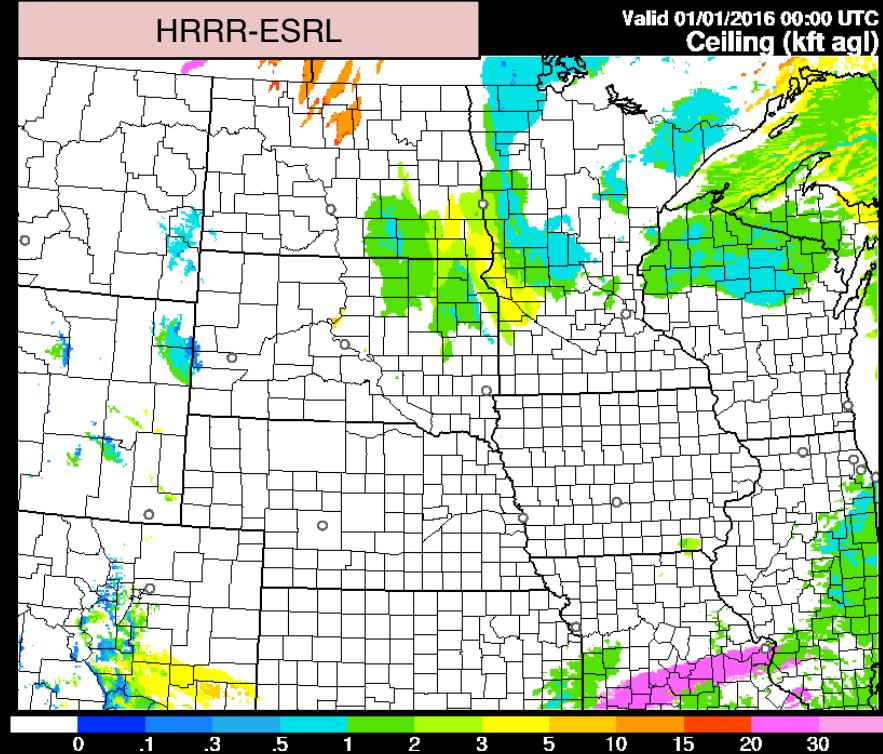


Example: 1 January 2016

HRSS w/new subgrid clouds + experimental ceiling diagnostic



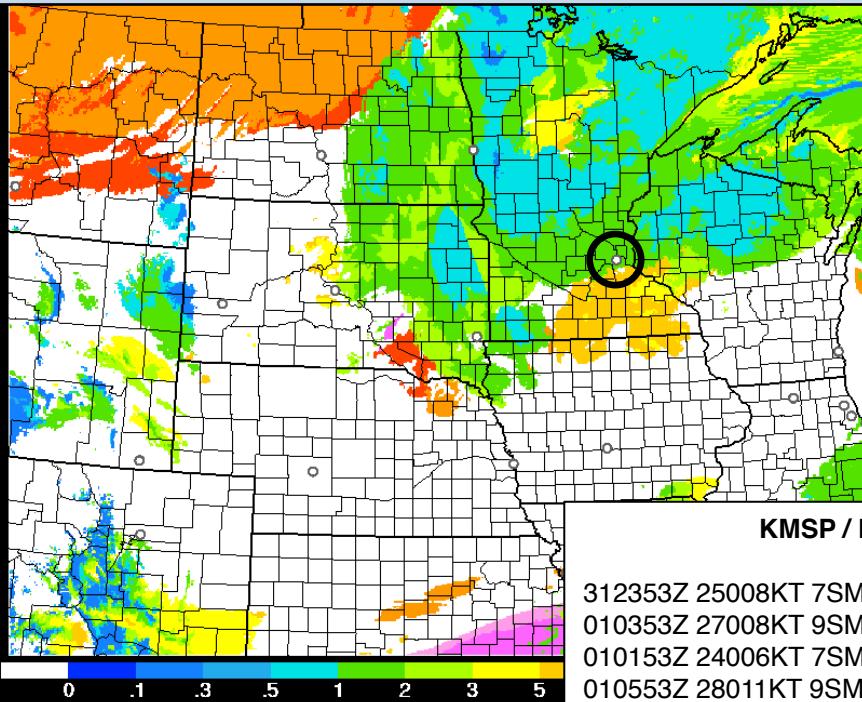
HRRR-ESRL



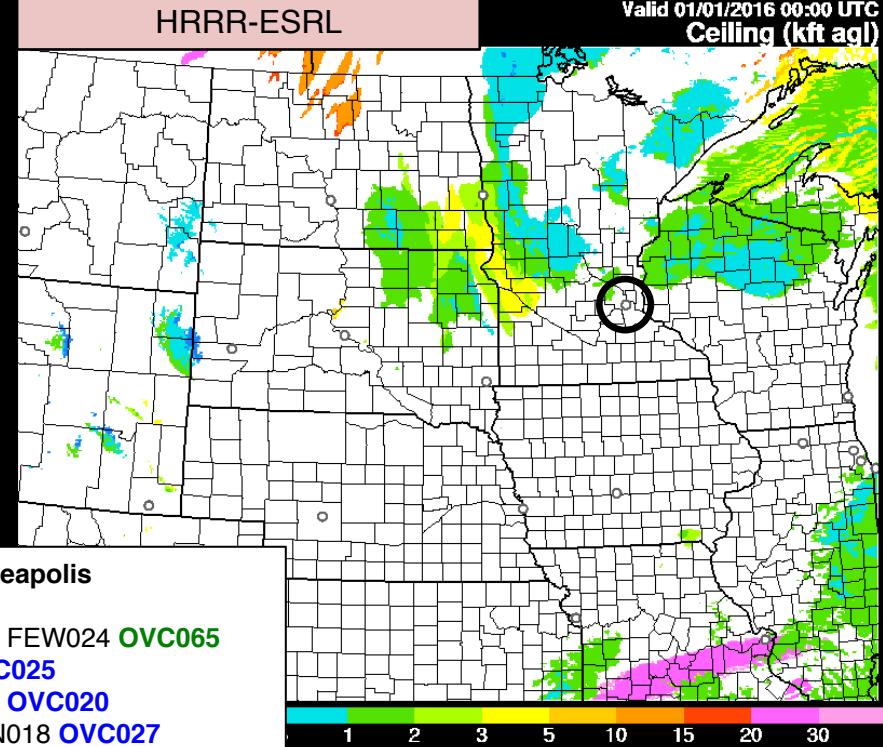


Example: 1 January 2016

HRRR w/new subgrid clouds + experimental ceiling diagnostic



HRRR-ESRL



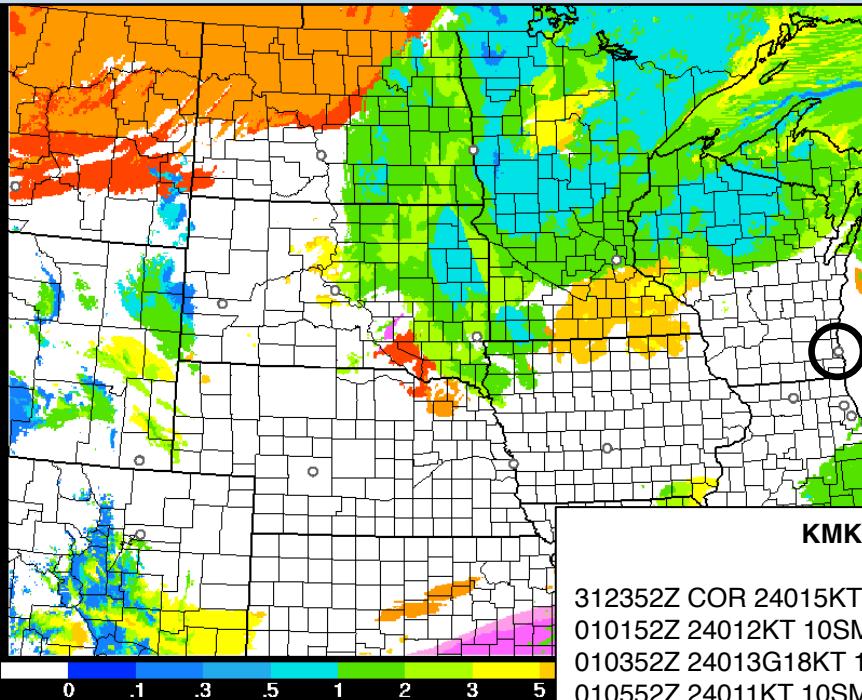
KMSP / Minneapolis

312353Z 25008KT 7SM -SN FEW024 OVC065
010353Z 27008KT 9SM OVC025
010153Z 24006KT 7SM -SN OVC020
010553Z 28011KT 9SM BKN018 OVC027
010753Z 26005KT 7SM OVC018



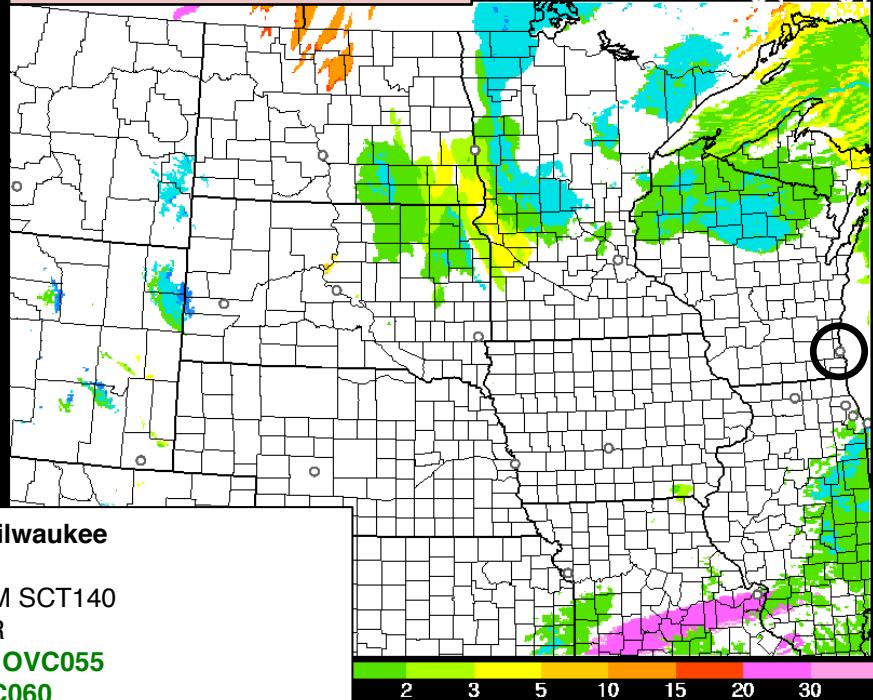
Example: 1 January 2016

HRRR w/new subgrid clouds + experimental ceiling diagnostic



HRRR-ESRL

Valid 01/01/2016 00:00 UTC
Ceiling (kft agl)

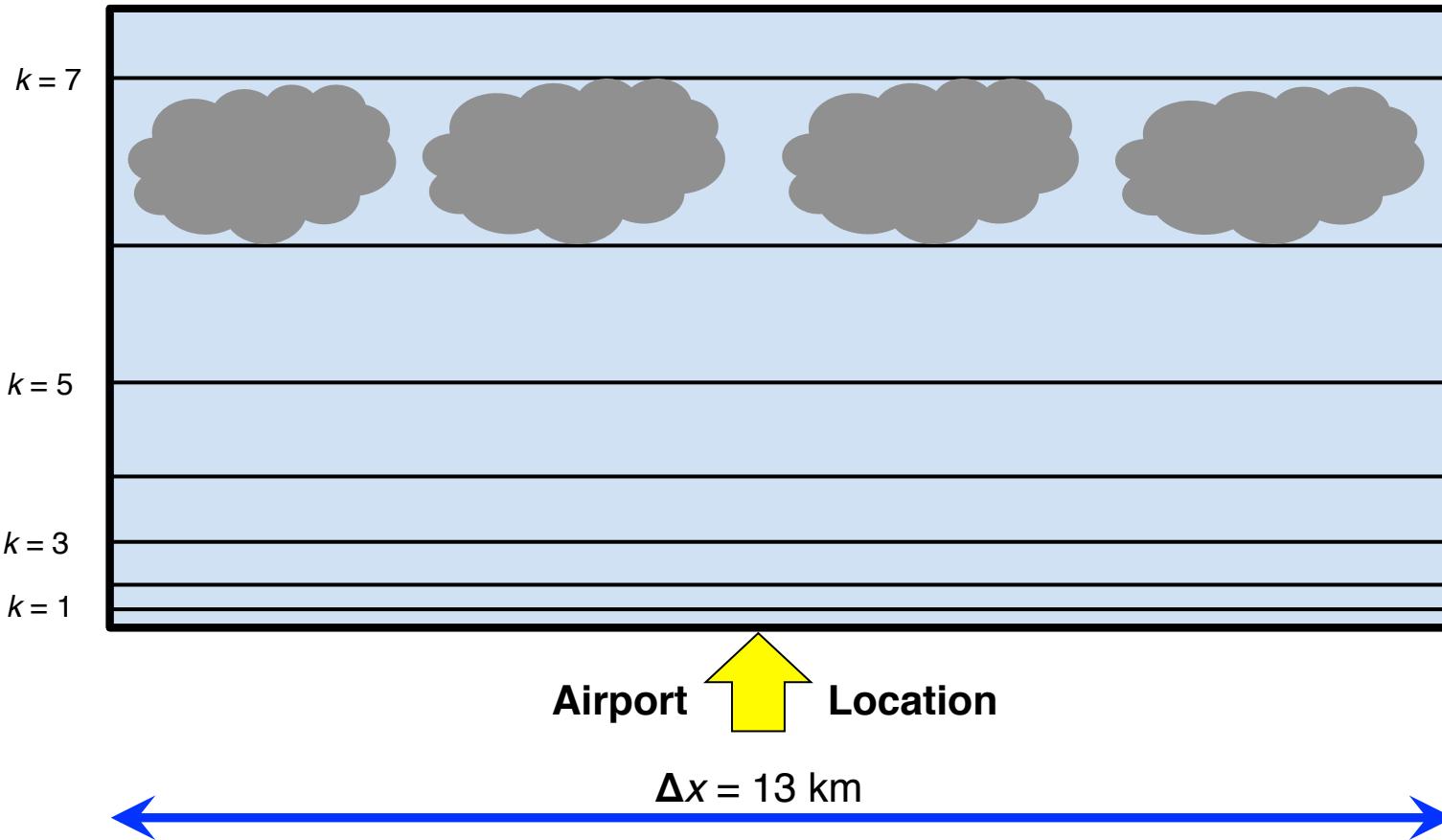


KMKE / Milwaukee

312352Z COR 24015KT 10SM SCT140
010152Z 24012KT 10SM CLR
010352Z 24013G18KT 10SM OVC055
010552Z 24011KT 10SM OVC060
010752Z 27013G20KT 10SM FEW020 BKN065

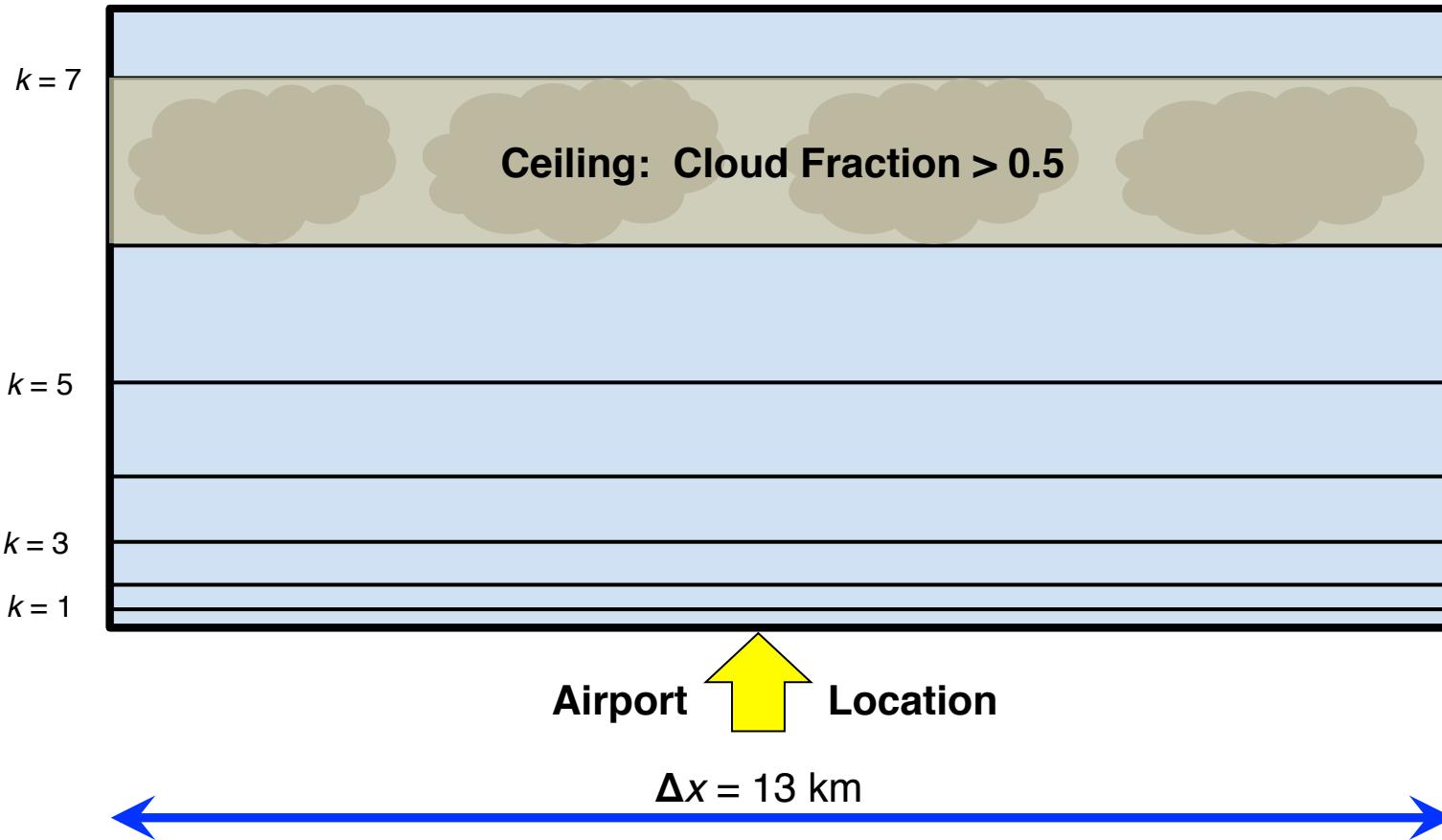


The Limits of a Single-Column Ceiling Diagnostic



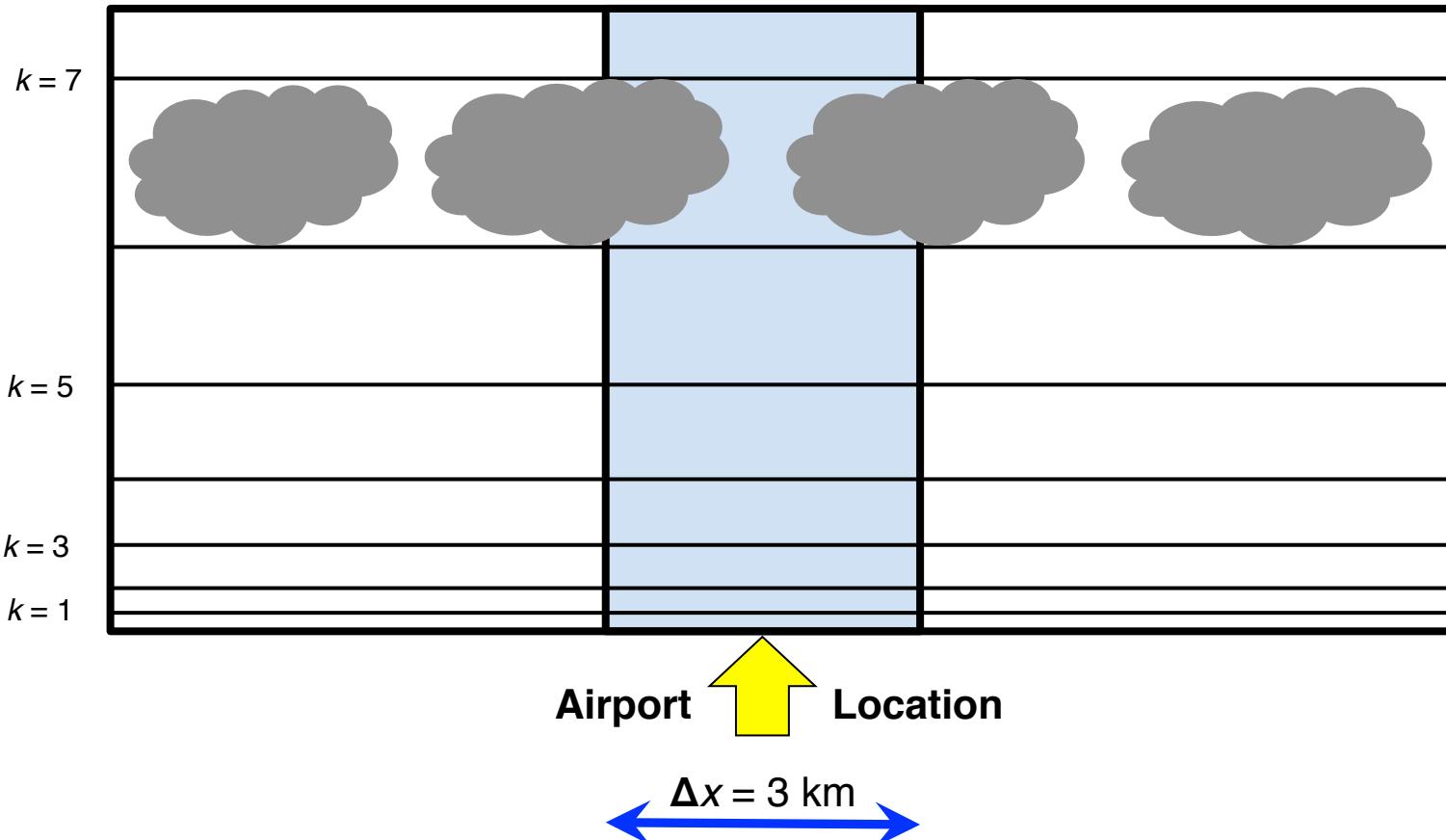


The Limits of a Single-Column Ceiling Diagnostic



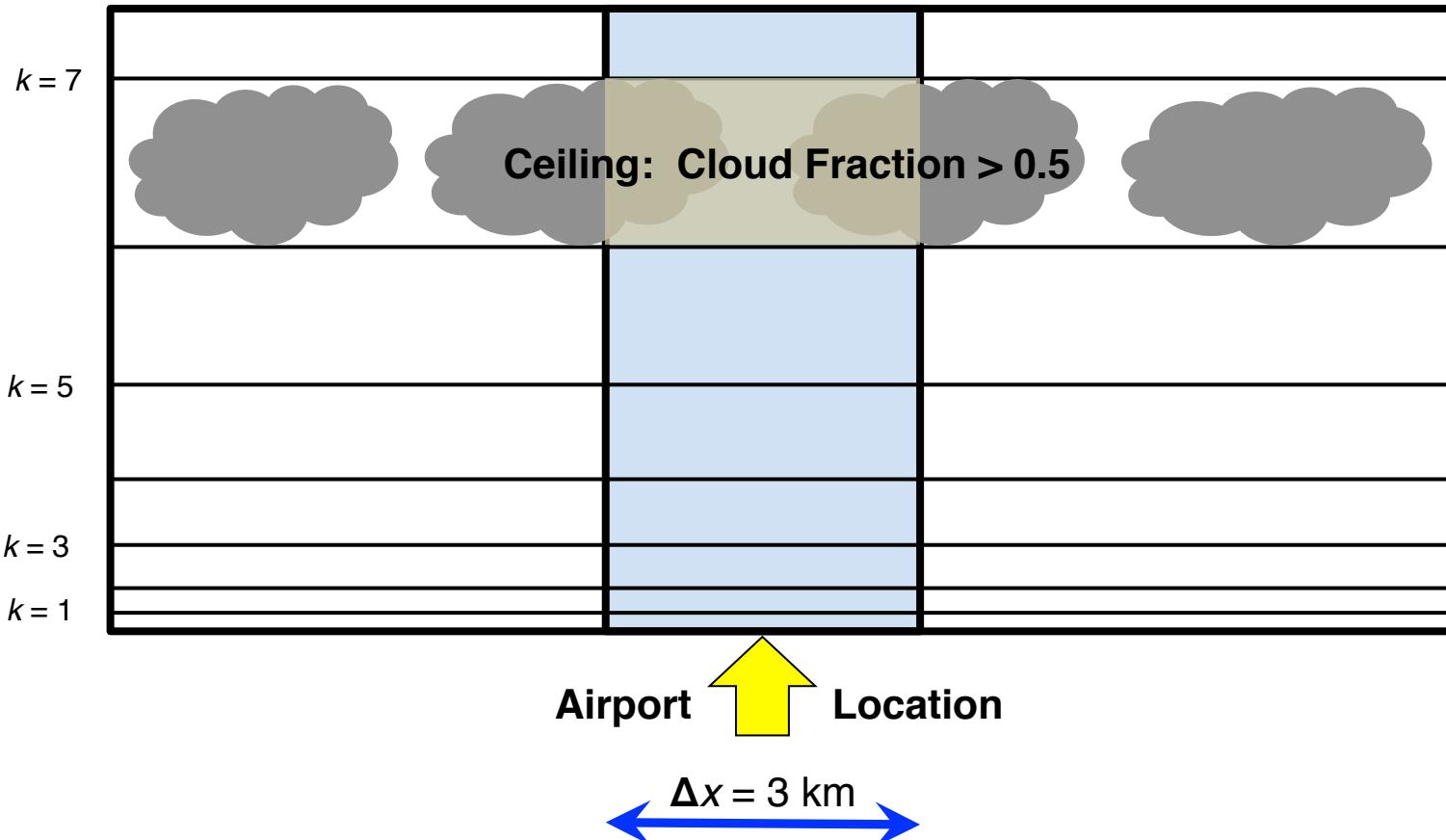


The Limits of a Single-Column Ceiling Diagnostic



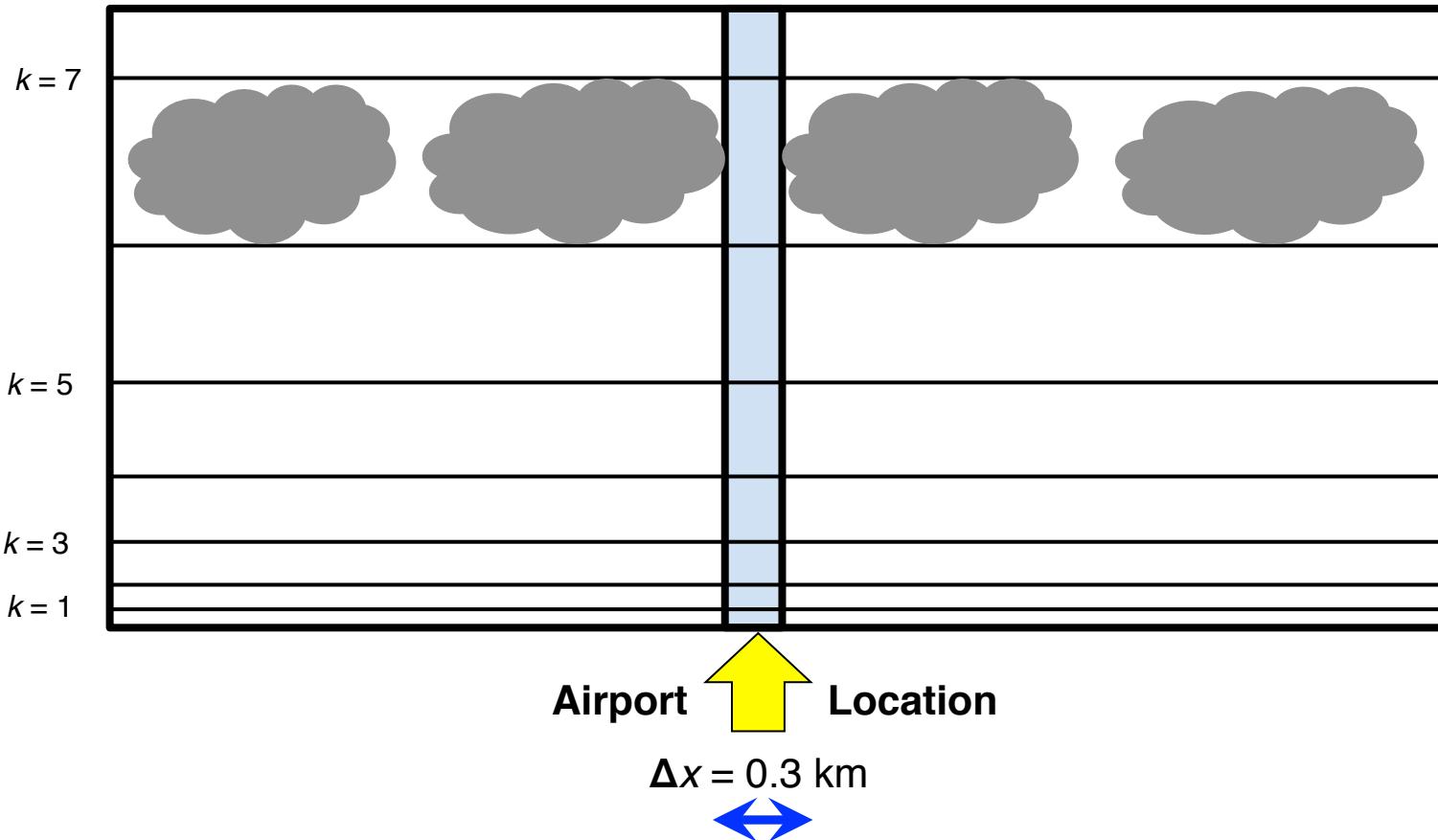


The Limits of a Single-Column Ceiling Diagnostic



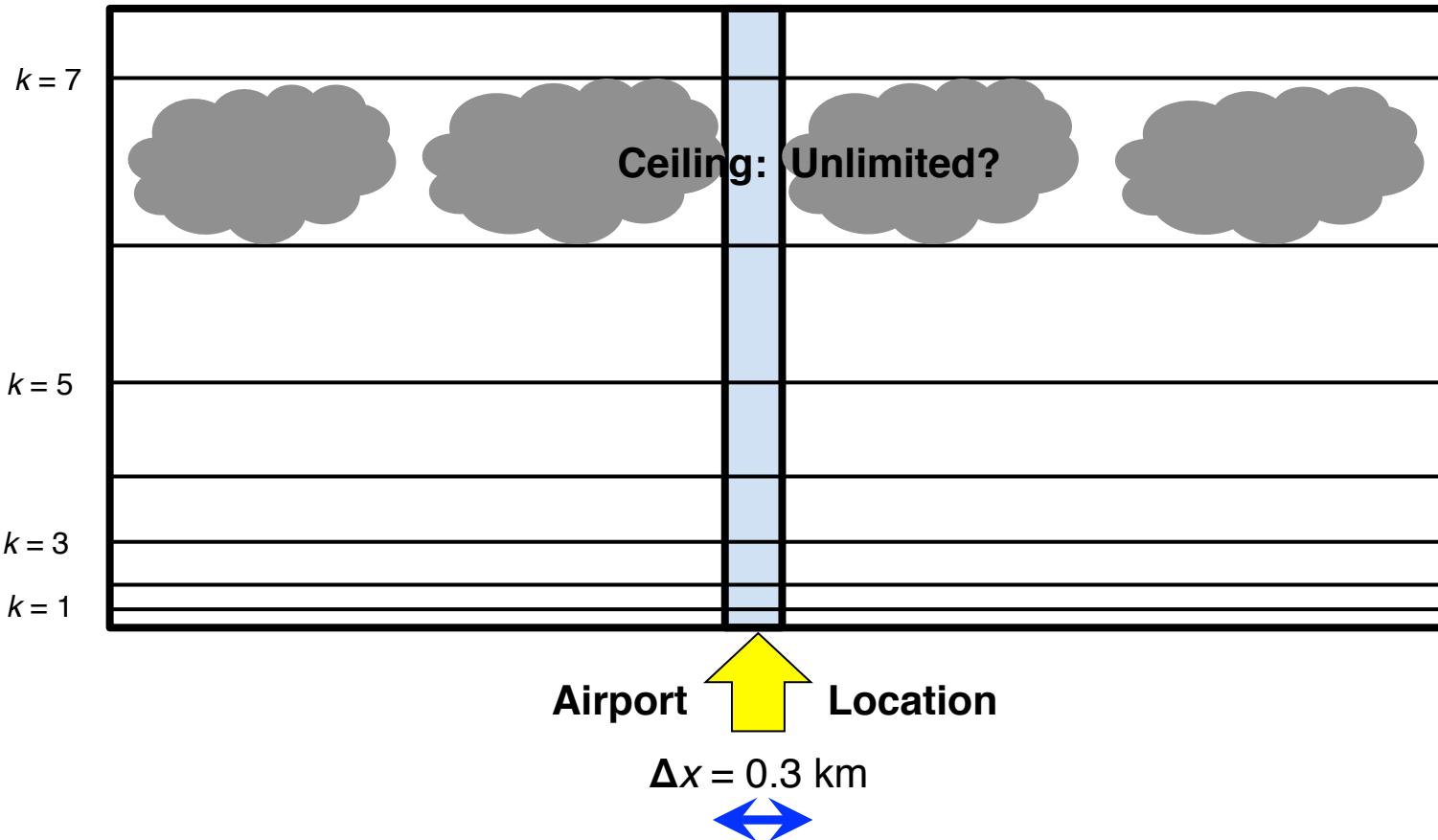


The Limits of a Single-Column Ceiling Diagnostic



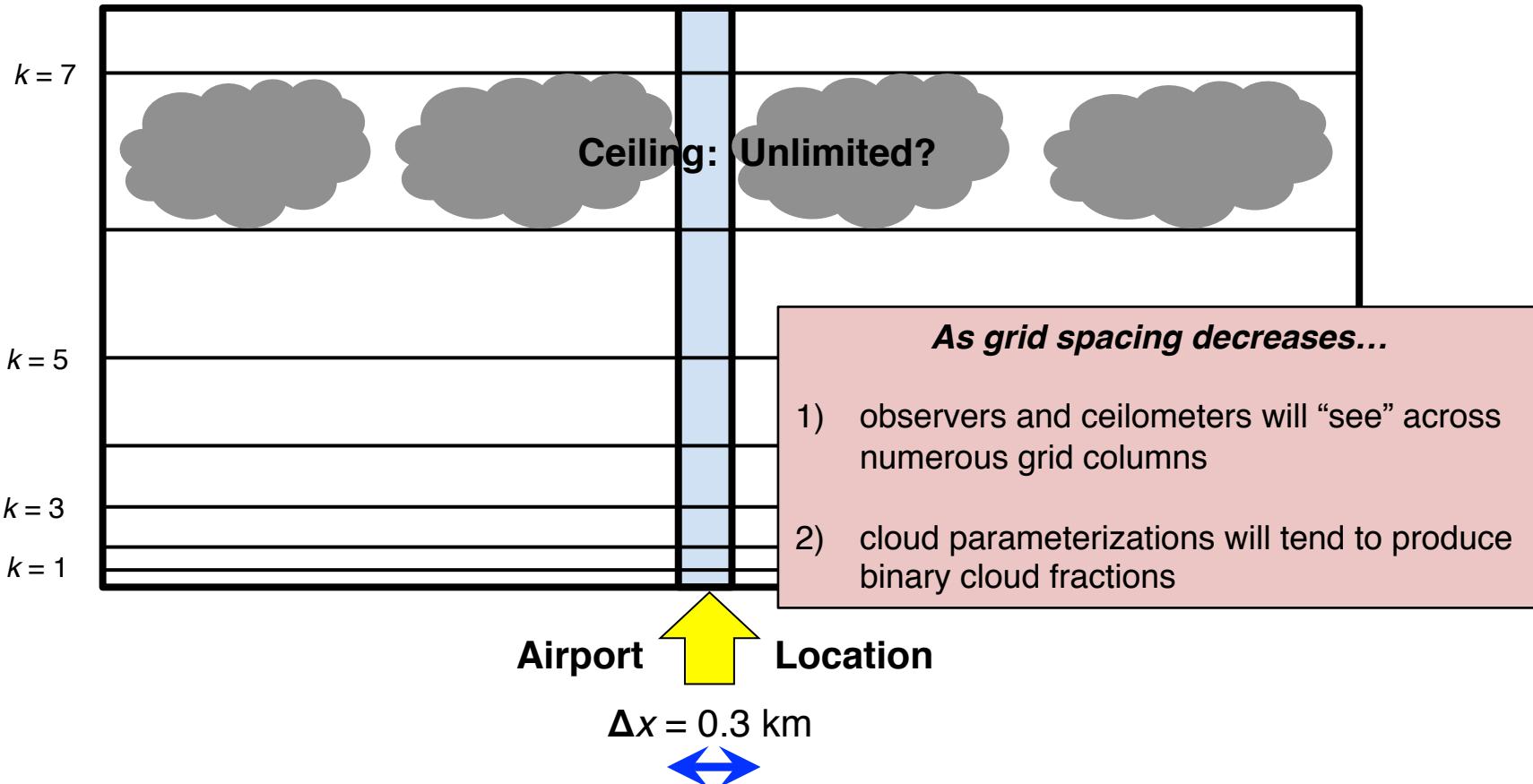


The Limits of a Single-Column Ceiling Diagnostic



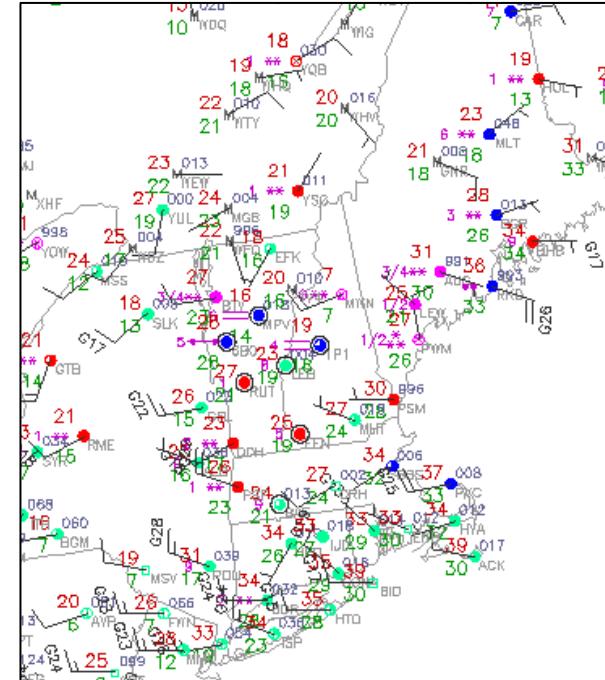


The Limits of a Single-Column Ceiling Diagnostic



Summary

- RAP / HRRR subgrid-scale cloud representation is being actively developed
- The Chaboureau and Bechtold (2002) scheme provides representation of subgrid stratus, cirrus
- A cloud-fraction-based ceiling diagnostic, paired with better subgrid cloud representation, may improve forecasts of low ceilings



Questions: Jaymes.Kenyon@noaa.gov



ESRL RAP and HRRR Configurations

Model	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	North America	758 x 567	13 km	50	10 hPa	GFS	Hourly (cycled)
HRRR	CONUS	1799 x 1059	3 km	50	20 hPa	RAP	Hourly - RAP (no cycling)

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Convection Deep/Shallow	PBL	LSM
RAP	WRF-ARW v3.6.1+	GSI Hybrid 3D-VAR/ Ensemble	13-km DFI	RRTMG/ RRTMG	Thompson-Eidhammer (aerosol-aware)	GF / GFO	MYNN	RUC 9-lev
HRRR	WRF-ARW v3.6.1+	GSI Hybrid 3D-VAR/ Ensemble	3-km 15-min LH	RRTMG/ RRTMG	Thompson-Eidhammer (aerosol-aware)	None / GFO	MYNN	RUC 9-lev

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6 th Order Diffusion	Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5 th /5 th	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	20 min	MODIS Fractional	0.01 K/s	60 s
HRRR	5 th /5 th	Positive-Definite	w-Rayleigh 0.2	Yes 0.25 (flat terr)	15 min	MODIS Fractional	0.07 K/s	20 s